National Aeronautics and Space Administration

Goddard Earth Science Data Information and Services Center (GES DISC)

README Document for

Reprocessing and Goddard Satellite-based Surface Turbulent Fluxes (GSSTF) Data Set for Global Water and Energy Cycle Research

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1. Introduction

This document provides basic information for using Goddard Satellite-based Surface Turbulent Fluxes (a.k.a. GSSTF2b) Data Set products.

The GSSTF2b consists of products generated for the focus on Global Water and Energy Cycle Research. The global water cycle's provision of water to terrestrial storage, reservoirs, and rivers rests upon the global excess of evaporation to precipitation over the oceans. Variations in the magnitude of this ocean evaporation excess will ultimately lead to variations in the amount of freshwater that is transported (by the atmosphere) and precipitated over continental regions. The air-sea fluxes of momentum, radiation, and freshwater (precipitation – evaporation) play a very essential role in a wide variety of atmospheric and oceanic problems (e.g., oceanic evaporation contributes to the net fresh water input to the oceans and drives the upper ocean density structure and consequently the circulation of the oceans). Information on these fluxes is crucial in understanding the interactions between the atmosphere and oceans, global energy, and water cycle variability, and in improving model simulations of climate variations.

1.1. Dataset Description

There are two sets of GSSTF, Version 2b, "Combined" data, "Set1" and "Set2" (July 1987-December 2008). They are different for being produced using a different combination of individual satellite products. Set1/Set2 may contain a larger/smaller global temporal trend in latent heat flux, but with less/more missing data. They are stored together in HDF-EOS5 files, under two separate Grids, SET1 and SET2.

The GSSTF, Version 2b, daily fluxes have first been produced for each individual available SSM/I (Special Sensor Microwave Imager) satellite tapes (e.g., F08, F10, F11, F13, F14 and F15). Then, the Combined daily fluxes are produced by averaging (equally weighted) over available flux data/files from various satellites. These Combined daily flux data are considered as the "final" GSSTF, Version 2b, and are stored in this HDF-EOS5 collection.

1.2. Algorithm Background

The bulk flux model (based on the surface layer similarity theory, Chou, 1993) used for performing the recently-produced/future production (GSSTF2b/GSSTF3) is essentially the same as that for GSSTF2 (Chou et al., 2003). Similar to GSSTF2, GSSTF2b and GSSTF3 require the same methodology and same kinds of input data such as the surface/10-m wind speeds (*U*), total precipitable water (W), bottom-layer (500 m) precipitable water (WB), SST, 2-m air temperature (*T*a), and sea level pressure (SLP). However, GSSTF2b used input datasets of an upgraded and improved version, i.e., U, W and WB of the SSM/I V6, and SST, Ta and SLP of the NCEP/DOE Reanalysis-2 (R2). The input datasets previously used for producing GSSTF2 were products of the SSM/I V4 and the NCEP R1. Moreover, a recently upgraded Cross-Calibrated Multi-Platform (CCMP) ocean surface wind vector product (Atlas et al., 2009), which was based on the same variational analysis method (VAM) applied for producing an earlier surface wind vector dataset (Atlas et al., 1996) used for determining the GSSTF2 wind stress vectors, has been used for the GSSTF2b production. Detailed info's on GSSTF2b can be found in Shie et al. (2009) and Shie et al. (2010).

The daily 1^o GSSTF2 turbulent fluxes were derived from the SSM/I surface winds and the GSSTF-retrieved surface air humidity, as well as the 2-m air and sea surface temperatures of the NCEP-NCAR reanalysis, using a bulk aerodynamic algorithm based on the surface layer similarity theory. The bulk flux model is currently under testing for a potential application with a more sophisticated setup of transfer coefficients, particularly concerning a high wind scenario, for the future production of GSSTF3. Transfer coefficients, which reflect efficiency of the vertical transportation of momentum, heat, and moisture flux, are a non-linear function of the vertical gradient in wind speed, temperature, and water vapor near the surface, and hence are affected by the stability of the surface air.

The coefficients increase with decreasing wind when the 10-m winds are less than 3 m s^{-1}*:* The GSSTF2 transfer coeffcients (for 10-m winds up to < 18 m s^{-1}) are in close agreement with those of Zeng et al. (1998), Fairall et al. (1996), and Renfrew et al. (2002). Liu et al. (1979) performed detailed analysis of the transfer coefficients based on their model. They predicted that under low wind conditions the transfer coefficient might increase with increasing wind speed, because the increased roughness facilitates the transfer of heat and vapor. However, as the wind speed increases further, the sheltering effect due to the troughs between waves becomes more significant and will suppress the exchange of vapor and heat. As the wind speed reaches about 5 m s^{-1}, the negative and positive effects due to increased wind speed counterbalance each other. If wind speed increases further, the transfer coefficient may even start to decrease. Andreas (1992) and Andreas et al. (1995) suggested that at wind speed of 20 m s^{-1}, the latent heat flux due to spray is of similar magnitude to the turbulent flux. The latest field and laboratory measurements have shown that the drag coefficient doesn't increase with wind speed at extreme wind conditions, i.e., greater than 30 m s^{-1} (Powell et al., 2003; Donelan et al., 2004). Therefore, high-wind transfer coefficients (based on Powell et al., 2003; Donelan et al., 2004; Black et al., 2007) may be considered for the 10-m winds beyond 18 m s^{-1} in the future production of GSSTF3.

1.3. Data Disclaimer

Data should be used with care and proper citations, i.e., properly indicating your applications with, e.g., "using the combined 2001 data file of Set1 (or Set2)" or "using the 2001 F13 data file". Set1 (involved with more satellite data) does not necessarily possess better real data quality than Set2. The users may feel free to use either Set1 or Set2 with their own interests and justifications (like they may also use the product of individual satellites).

2. Data Organization

2.1. HDF-EOS5 products resulting from GSSTF2b

The original GSSTF2b collections are in binary format, and their organization is described in:

ftp://meso-a.gsfc.nasa.gov/pub/shieftp/fluxdata/README-General
ftp://meso-a.gsfc.nasa.gov/pub/shieftp/fluxdata/README-Data
ftp://meso-a.gsfc.nasa.gov/pub/shieftp/fluxdata/README-Set1
ftp://meso-a.gsfc.nasa.gov/pub/shieftp/fluxdata/README-Set2
ftp://meso-a.gsfc.nasa.gov/pub/shieftp/fluxdata/README-Climatology

The MEaSUREs project at GES DISC, however, converted all data into HDF-EOS5 format and reorganized it into separate daily and monthly files, in a manner consistent with the on-going Earth Observing System (EOS) missions such as Aura, Aqua, and Terra. The monthly, seasonal and yearly climatologies are also in HDSF-EOS5 format, in separate files. I.e. the daily files are now easily searchable and downloadable by data day (section 5).

The essential meaning of HDF-EOS5 is that the data are now in a standard “Grid” format. The Set1 and Set2 eight major variables are grouped into two separate grids, named “SET1” and “SET2”, and the two grids are stored together in one file. Further, the “minor” variable - total precipitable water - is grouped together with the eight major variables in the corresponding SET1 or SET2 grid. Thus each grid contains 9 variables. This organization is identical for all daily and monthly files, apart from the model reanalysis. The “common”, NCEP/DOE Reanalysis II, data are stored in separate files with one Grid containing the four “common” variables. The climatologies (monthly, seasonal, and yearly) also contain the SET1 and SET2 grids, but in addition are also containing the four NCEP variables in a separate grid.

The “individual tapes” representing the individual SSM/I satellites are stored in separate collections and daily files, one day per file. They contain one grid that is named on the satellite name (F08, F10, F11, F13, F14, and F15). The grid contains the nine variables (8 major + 1 minor) that go into the computation of the final nine “combined” retrieved variables.

All data within these HDF-EOS5 are easily recognizable as 360x180 arrays, representing global map, at 1x1 deg grid cell size. The endian-ess of the remote storage and users’ local machines become irrelevant. The concept of headers and offsets, typical for the binary format, disappears and all that matters are Grid and data field names that are very easy to list out using command line utilities. Examples are listed in section 4.1.

This data organization results in 13 data types, with Short Names listed below. The Short Name is the first string in all filenames, and it is also stored inside the files as a global file attribute “ShortName”.

A. Daily:

There are total of Eight (8) daily data types.

GSSTF
GSSTF_NCEP
GSSTF_F08
GSSTF_F10
GSSTF_F11
GSSTF_F13
GSSTF_F14
GSSTF_F15

1) GSSTF
It has 2 grids, "SET1" and "SET2". Every grid has 9 parameters, the 8 "major" plus the "minor" total precipitable water.

2) GSSTF_NCEP
It has one grid, "NCEP", with 4 parameters. The original were the "common" binary files, that is the NCEP/DOE Reanalysis II.

3)GSSTF_Fxx
These are the individual satellites, where Fxx is one of the following (F08, F10, F11, F13, F14, and F15). The HDF-EOS5 files have only one grid which takes the name of the individual satellite. Every grid has 9 parameters, the 8 "major" plus the "minor" total precipitable water.

B. Monthly:
There are two Monthly data types in he5.
GSSTFM
GSSTFM_NCEP

1) GSSTFM
It has four (4) grids: SET1, SET1_INT, and SET2, SET2_INT, where "INT" stands for interpolated. Each of these has 9 (nine) parameters: the 8 "major" plus the "minor" total precipitable water.

2)GSSTFM_NCEP
This is the "common" monthly NCEP/DOE Reanalysis II. It has one grid with four parameters.

C. Climatology
There are three (3) climatological data types: Monthly, Seasonal, and Yearly in HDF-EOS5:
GSSTFMC

GSSTFSC
GSSTFYC

The climatologies (monthly, seasonal, and yearly) also contain the SET1 and SET2 grids, but in addition are also containing the four NCEP/DOE Reanalysis II variables in a separate grid, "NCEP".

Summary of All Data Types:
GSSTF
GSSTF_NCEP
GSSTF_F08
GSSTF_F10
GSSTF_F11
GSSTF_F13
GSSTF_F14
GSSTF_F15
GSSTFM
GSSTFM_NCEP
GSSTFMC
GSSTFSC
GSSTFYC

2.2. File Naming Convention

The file naming convention for the non-climatological HDF-EOS5 files produced at GES DISC for the GSSTF2b project is as follows:

ShortName.vv.yyyy.mm.dd.he5

Where:

- ShortName = one of the following Data Types:
  GSSTF
  GSSTF_NCEP
  GSSTF_F08
  GSSTF_F10
  GSSTF_F11
  GSSTF_F13
  GSSTF_F14
  GSSTF_F15
  GSSTFM
  GSSTFM_NCEP

GSSTFMC
GSSTFSC
GSSTFYC

- vv = 2b for this release
- yyyy = data year
- mm= data month
- dd = start date for the data
- he5 = commonly accepted extension for HDF-EOS5 files.

Filename example for the daily “combined” turbulent fluxes retrieval, for November 1, 2000:
GSSTF.2b.2000.11.01.he5

Climatologies have slightly different file names that reflect the Month (for monthlies), and the range of Months (for seasonal), and the range of years for which the climatology is built. The yearly climatology has one file only.

Example file name for Monthly climatology for November:

GSSTFMC.2b.Nov.1988_2008.he5

Example file name for seasonal climatology for September-November:

GSSTFSC.2b.Sep_Nov.1988_2008.he5

2.3. File Format and Structure

GSSTF2b files are in HDF-EOS5 format, which is an extension of the Hierarchical Data Format Version 5 (HDF-5), developed at the National Center for Supercomputing Applications http://www.hdfgroup.org/. This extension facilitates the creation of a standard Grid data structures that are relevant to this project. All data arrays represent global map of size 360x180 (columns x rows) grid cells.

Thanks to the HDF-EOS5 format, the **path** to the data fields inside the file is always standardized. For the Grid format, it is always of the form:

/HDFEOS/GRIDS/<grid_name>/Data Fields/<data_field_short_name>.

For example, the sensible heat flux in all relevant GSSTF2b files in HDF-EOS5 will be found under this path:

/HDFEOS/GRIDS/SET1/Data Fields/H

Thus, users need to know only the grid_name and the data_field_short_name. The rest of the path is standard.

2.4. Key Science Data Fields

In the tables below, the data_field_short_name is the one that is used in the HDF-EOS5 path inside the files to uniquely identify a data field. The long name is an attribute to the particular data field that serves as a short description of the field.

Each **SET1** or **SET2** grid (including interpolated, SET1_INT, SET2_INT) contains the following 9 science data fields:

data_field_short_name	Data field long name (units)
"E"	'latent heat flux' (W/m**2)
"STu"	'zonal wind stress' (N/m**2)
"STv"	'meridional wind stress' (N/m**2)
"H"	'sensible heat flux' (W/m**2)
"Qair"	'surface air (~10-m) specific humidity' (g/kg)
"WB"	'lowest 500-m precipitable water' (g/cm**2)
"U"	'10-m wind speed' (m/s)
"DQ"	'sea-air humidity difference' (g/kg)
"Tot_Precip_Water"	'total precipitable water' (g/cm**2)

Each NCEP Grid contains the following 4 data fields:

Data field short name	Data field long name (units)
"SST"	'sea surface skin temperature' (C)
"Psea_level"	'sea level pressure' (hPa)
"Tair_2m"	'2m air temperature' (C)
"Qsat"	'sea surface saturation humidity' (g/kg)

2.5. Science Area

The global water cycle’s provision of water to terrestrial storage, reservoirs, and rivers rests upon the global excess of evaporation to precipitation over the oceans. Variations in the magnitude of this ocean evaporation excess will ultimately lead to variations in the amount of freshwater that is transported (by the atmosphere) and precipitated over continental regions. The air-sea fluxes of momentum, radiation, and freshwater (precipitation – evaporation) play a very essential role in a wide variety of atmospheric and oceanic problems (e.g., oceanic evaporation contributes to the net fresh water input to the oceans and drives the upper ocean density structure and consequently the circulation of the oceans). Information on these fluxes is crucial in understanding the interactions between the atmosphere and oceans, global energy, and water cycle variability, and in improving model simulations of climate variations.

3. Data Contents

3.1. Dimensions

All data fields in the GSSTF2b data types represent global maps of size 360x180 (columns x rows) grid cells. This corresponds to 1x1 degree cylindrical (Mercator) map representation. There only two dimension names in the grid structure, Xdim and Ydim, that address the longitude, and latitude, respectively.

3.2. Global Attributes

In addition to SDS arrays containing variables and dimension scales, global metadata is also stored in the files. Some metadata are required by standard conventions, some are present to meet data provenance requirements and others as a convenience to users of **GSSTF2b** products. Under the HDF-EOS5 standards, the global (file) attributes are grouped under the following path:

/HDFEOS/ADDITIONAL/FILE_ATTRIBUTES

Global Attribute	Type	Description
BeginDate	Character string	Begin time of data
EndDate	Character string	End time of data
Set2eqSet1	Character string	"T" if Set2 data is a copy of Set1; "F" otherwise
ShortName	Character string	Short name of the data type (collection) from section 2.1
LongName	Character string	Long name of the collection
CollectionDescription	Character string	Description of the collection

Apart from the global (file) attributes, every data field has its own "local" attributes. Presently there are only three local attributes:

_FillValue
LongName
Units

_FillValue=-999 is preserved from the binary originals for the entire GSSTF2b collection. The LongName and the Units were described above and can be found in the tables of Sec. 2.4.

4. Options for Reading the Data

4.1. Command Line Utilities

The HDF Group lists a number of HDF5 command line tools on their website:

http://www.hdfgroup.org/products/hdf5_tools/index.html#h5dist

Among them, the one that is the most useful for previewing HDF5 content is **h5dump**. Since the HDF-EOS5 is just a standard-structured HDF5, the entire functionality of h5dump is fully preserved. H5dump is the tool to use to have a very first look at any HDF5-formatted file, even if no documentation describing data is available. The tool by itself does not need extensive documentation, it is very straightforward to use and its all options can be conveniently listed at the command line using the help option "-h":

h5dump –h

As of the current naming setup of the data fields, a simple list request "-n" will produce the following output, where full paths to groups and individual data fields (dataset) are obvious:

h5dump -n GSSTF.2b.1998.12.19.he5

```
HDF5 "GSSTF.2b.1998.12.19.he5" {
FILE_CONTENTS {
 group      /
 group      /HDFEOS
 group      /HDFEOS/ADDITIONAL
 group      /HDFEOS/ADDITIONAL/FILE_ATTRIBUTES
```

```
group     /HDFEOS/GRIDS
group     /HDFEOS/GRIDS/SET1
group     /HDFEOS/GRIDS/SET1/Data Fields
dataset   /HDFEOS/GRIDS/SET1/Data Fields/DQ
dataset   /HDFEOS/GRIDS/SET1/Data Fields/E
dataset   /HDFEOS/GRIDS/SET1/Data Fields/H
dataset   /HDFEOS/GRIDS/SET1/Data Fields/Qair
dataset   /HDFEOS/GRIDS/SET1/Data Fields/STu
dataset   /HDFEOS/GRIDS/SET1/Data Fields/STv
dataset   /HDFEOS/GRIDS/SET1/Data Fields/Tot_Precip_Water
dataset   /HDFEOS/GRIDS/SET1/Data Fields/U
dataset   /HDFEOS/GRIDS/SET1/Data Fields/WB
group     /HDFEOS/GRIDS/SET2
group     /HDFEOS/GRIDS/SET2/Data Fields
dataset   /HDFEOS/GRIDS/SET2/Data Fields/DQ
dataset   /HDFEOS/GRIDS/SET2/Data Fields/E
dataset   /HDFEOS/GRIDS/SET2/Data Fields/H
dataset   /HDFEOS/GRIDS/SET2/Data Fields/Qair
dataset   /HDFEOS/GRIDS/SET2/Data Fields/STu
dataset   /HDFEOS/GRIDS/SET2/Data Fields/STv
dataset   /HDFEOS/GRIDS/SET2/Data Fields/Tot_Precip_Water
dataset   /HDFEOS/GRIDS/SET2/Data Fields/U
dataset   /HDFEOS/GRIDS/SET2/Data Fields/WB
group     /HDFEOS INFORMATION
dataset   /HDFEOS INFORMATION/StructMetadata.0
```

It is easy to distinguish Set1 and Set2 groups, and the associated data fields that are always under the group “Data Fields”. The dataset “StructMetadata.0” is written by the HDF-EOS5 libraries, during the process of the Grid structures creation. It can also be inspected by more advanced users, to validate dimensions and data organization (note, some outputs can be very long, so they are abbreviated here for clarity):

```
h5dump -d "/HDFEOS INFORMATION/StructMetadata.0"  GSSTF.2b.1998.12.19.he5
```

…

```
    GROUP=GridStructure
      GROUP=GRID_1
         GridName="SET1"
         XDim=360
         YDim=180
         UpperLeftPointMtrs=(-180000000.000000,-90000000.000000)
         LowerRightMtrs=(180000000.000000,90000000.000000)
         Projection=HE5_GCTP_GEO
         GROUP=Dimension
            OBJECT=Dimension_1
               DimensionName="Xdim"
```

```
            Size=360
        END_OBJECT=Dimension_1
        OBJECT=Dimension_2
            DimensionName="Ydim"
            Size=180
        END_OBJECT=Dimension_2
    END_GROUP=Dimension
    GROUP=DataField
        OBJECT=DataField_1
            DataFieldName="E"
…
```

The option -d can be used to list numerical datasets, too:

```
h5dump -d "/HDFEOS/GRIDS/SET2/Data Fields/E" GSSTF.2b.1998.12.19.he5
…
  (75,165): 196.857, 191.538, 191.316, 184.728, 184.373, 198.597, 188.133,
  (75,172): 178.673, 177.775, 181.975, 169.355, 146.068, 124.323, 112.992,
  (75,179): 102.341, -999, 84.1494, 72.4783, 73.2529, 77.3465, 76.4261,
  (75,186): 80.3385, 84.5448, 76.2291, 58.7598, 26.8386, -999, -999, -999,
…
```

where numbers in parentheses indicate (row, column).

4.2. Tools for simple visualization and file content view.

Among these, **HDFView** is one of the simplest to use and install on your local desktop. A strength of HDFView is that it is good for both, HDF4 and HDF5, formats and it will open files in both formats seamlessly for the user. Another strength is that file content is presented graphically in a very friendly fashion – all groups are presented as folders where user can easily drill down the file hierarchy, which is especially useful for HDF5. Numerical data sets can be viewed as spreadsheets, and as images (multi-dimensional datasets). Simple data manipulations are possible. For download and more information, follow this link:

http://www.hdfgroup.org/hdf-java-html/hdfview/index.html

There are many other free tools for HDF viewing.

Panoply, developed at the Goddard Institute for Space Studies (GISS), is compliant with NetCDF Climate and Forecast (CF) Metadata Convention that is gaining popularity. A strength of the tool is that data can be previewed “remotely” over the network – i.e. user can preview file content of HDF files stored on a remote site, without downloading them. Panoply is available from GISS:

http://www.giss.nasa.gov/tools/panoply/

The two major commercial data languages, **IDL** and **MatLAB**, are coming with their libraries that fully support all HDF formats.

5. Data Services

GES DISC provides basic temporal and advanced (event) searches through its search and download engine, **Mirador:**

http://mirador.gsfc.nasa.gov/

Mirador offers various download options that suit users with different preferences and different levels of technical skills. Users can start from a point where they don’t know anything about these particular data, its location, size, format, etc.., and quickly find what they need by just providing relevant keywords, like “GSSTF2b”, or “flux”, or “turbulence”, or just “Heat”.

As the project progresses, more services will be added that will allow options for subsetting, format conversion, and previews using open source software such as OPeNDAP and Panoply.

6. More Information

All GSSTF2b data types are published to the Global Change Master Directory:

http://gcmd.nasa.gov

This is a centralized depository of climate data information that is catalogued by popular keywords, which facilitate data discovery. Since the Directory is visited by a large number of people working on a broad range of research topics, it is an excellent forum to popularize data collections. It also serves as source of data type information for Mirador.

7. Acknowledgements

The creators for GSSTF2b are:

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